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RECONNAISSANCE IN THE SOUTHERN WASATCH MOUNTAINS, UTAH[1]

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CONTENTS

INTRODUCTION
  Previous work
THE COTTONWOOD DISTRICT
  Structure
  Summary of Structural Evidence
  Stratigraphy
THE AMERICAN FORK–ALPINE DISTRICT
THE PROVO DISTRICT
THE SANTAQUIN–MOUNT NEBO DISTRICT
  Stratigraphy
  Structure
    Overthrusts
    Block faults
SUMMARY

INTRODUCTION

The facts here presented were gathered during a reconnaissance of the ore deposits in central Utah for the United States Geological Survey during the summer of 1912. No time was available for thorough areal work, but certain of the results obtained in the southern half of the Wasatch Mountains seem to be of sufficient interest for presentation. The districts visited in the Wasatch country were the Big and Little Cottonwood districts, where the writer accompanied Mr. B. S. Butler of the Survey, the American Fork and Alpine districts, the Provo district, and the Santaquin–Mount Nebo district (see Fig. 1).

Previous work.—The only published accounts of previous areal work on the bedrock geology of the region are in the report of the

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[1] Published by permission of the Director of the United States Geological Survey.

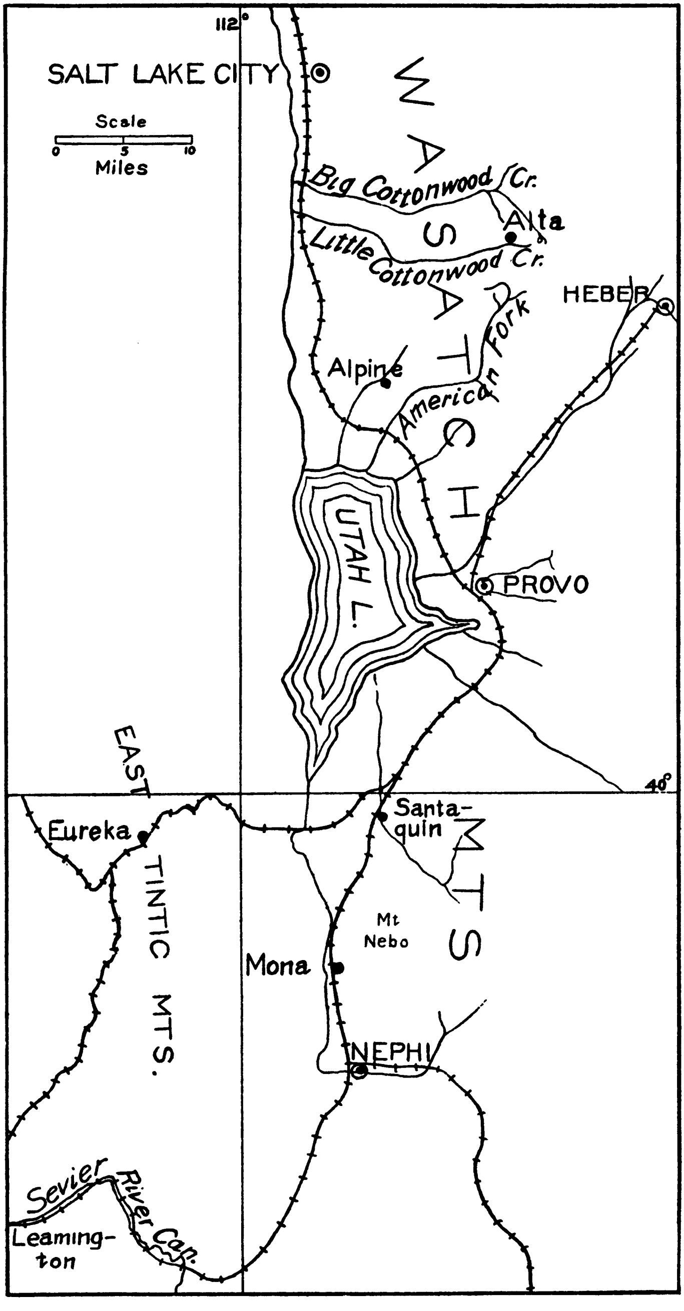

FIG. 1.—Sketch map showing positions of places mentioned in the text

Fortieth Parallel Survey, and that on the Park City mining district by Boutwell. Mr. F. S. Emmons, of the Fortieth Parallel Survey,[1] mapped the geology of the Wasatch Mountains from Provo Peaks northward, and his report gives brief mention of Mount Nebo 25 miles farther south—the highest and southernmost peak of the range. Mr. Emmons had only three weeks for his entire work in the Wasatch Mountains, and the amount of ground covered and the great quantity of data gathered by him in that time are indeed wonderful. It is only to be expected that his traverses did not lead him to all the places where the clues to stratigraphy and structure were exposed, and that in the absence of those clues certain evidence could not be finally interpreted. It is, however, a relatively easy matter for one aided by the Fortieth Parallel map to investigate certain special problems and to find evidence which modifies the interpretations originally given.

Boutwell has done considerable work in the country around the Cottonwood and American Fork districts,[2] and has thrown much light on the geology of both the igneous and sedimentary rocks; but his published detailed work on the latter deals chiefly with formations stratigraphically higher than those considered here, and the detailed descriptions of structure are confined to an area farther east than that visited by the writer. Boutwell, however, was the first to recognize overthrust faulting in the Wasatch Mountains.[3]

Blackwelder in 1910[4] made some interesting contributions to our knowledge of the northern Wasatch Mountains, eliminating the "Ogden (Devonian)" quartzite of the Fortieth Parallel Survey and discovering several great overthrust faults. He also examined the Big Cottonwood Canyon section and found an unconformity in the great quartzite series, correlating the overlying 1,500 ft. of the quartzite as Cambrian and the underlying 10,500 ft. as Algonkian.

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[1] *U.S. Geol. Explor. of the Fortieth Parallel*, II (1877), 342–66.

[2] J. M. Boutwell, "Geology and Ore Deposits of the Park City District, Utah," *Prof. Paper 77, U.S. Geol. Survey*, 1912.

[3] J. M. Boutwell, "Stratigraphy and Structure of the Park City Mining District, Utah," *Jour. Geol.*, XV (1907), 456–57.

[4] E. Blackwelder, "New Light on the Geology of the Wasatch Mountains, Utah," *Bull. Geol. Soc. of America*, XXI (1910), 517–42.

The results here presented are essentially a sequel to Blackwelder's work. To avoid repetition the evidence will be considered by districts rather than according to stratigraphy and structure.

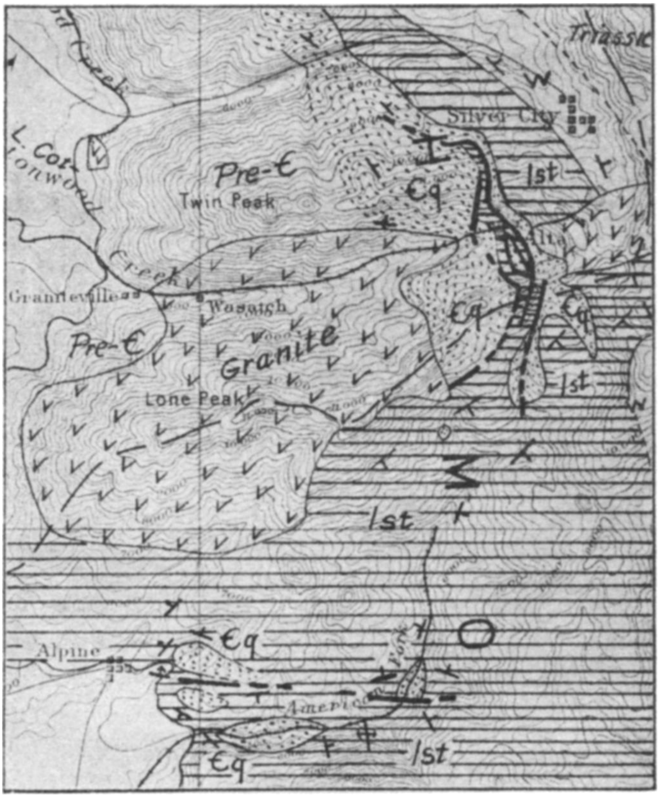

FIG. 2.—Geologic map showing the intrusive granite (probably post-Jurassic), Cambrian quartzite (-Ꞓq), and the great Cambrian to Mississippian limestone belt (*lst*) in the Cottonwood and American Fork–Alpine districts. The width of the narrow "lower" limestone belt at Alta is somewhat exaggerated. *W* = Weber quartzite; *Pre-Ꞓ* = pre-Cambrian. Topographic base taken from the Salt Lake sheet, United States Geological Survey.

THE COTTONWOOD DISTRICT[1]

Structure.—The arrangement of formations in this district is, as shown in Fig. 2, and more completely on the Fortieth Parallel

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[1] The term Cottonwood district is here used to include the area around the upper parts of Big and Little Cottonwood canyons.

Survey map, a rudely elliptical mass of granite surrounded on three sides by a concentric succession of sedimentary rocks. The granite, originally called Archean, was proved by Mr. Emmons in 1903[1] to be intrusive and probably of post-Jurassic age and his conclusions have been sustained by Boutwell.[2] The sedimentary rocks were originally correlated as follows:

Permo-Carboniferous and later
Upper Coal Measures limestone
Weber quartzite, Carboniferous
Wasatch limestone (intercalated series at the top), mostly lower Coal Measures
Ogden quartzite, Devonian
Ute limestone, Silurian
Quartzite (clay slates at the top), Cambrian

The present writer, however, during his first day in the district found fossils in the lower limestone belt (called the "Ute" in the above table) of Madison (Lower Mississippian) age. These fossils were collected on the spur between the two cirques just over the divide northwest of Alta, and were determined by Dr. Girty of the Survey as follows:

Syringopora sp.
Zaphrentis sp.
Amplexus sp.
Spirifer centronatus
Syringothyris (?) sp.
Composita sp.
Cleiothyridina crassicardinalis
Euomphalus sp.

These fossils are in part duplicated by fossils found in the great upper limestone belt (the "Wasatch" limestone of the Fortieth Parallel Survey), the greater part of which appears to be of Madison age. The fossils collected from this belt were determined by Dr. Girty as follows:

Syringopora sp.
Zaphrentis sp.
Spirifer centronatus

The presence of two belts of Mississippian limestone separated by a quartzite belt at once suggested the presence of an overthrust fault, which is proved by the following evidence. The "lower" limestone extends northward for about half-way down the Mill D

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[1] S. F. Emmons, *Amer. Jour. Science*, 4th series, XVI (1903), 139-47.

[2] J. M. Boutwell, *op. cit.*, p. 156.

South Fork of Big Cottonwood Creek, where it appears to be overridden by the "upper" quartzite (the "Ogden" in the above table), which here rests directly, though discordantly, upon the lower (Cambrian) quartzite. The "lower" limestone is absent to the northwest in Big Cottonwood Canyon. Southward from Alta the "lower" limestone extends in a synclinal attitude between the two quartzite belts as far as the head of American Fork Canyon, where it passes through a complication of faults and local contortions and finally merges into the great "upper" limestone belt (see Fig. 2). Middle Cambrian fossils found by Mr. Butler in shale members of the "upper" quartzite both north and south of Alta confirm the structural evidence of an overthrust. These fossils were determined by L. D. Burling as follows:

Zacanthoides cf. spinosus
Obolus (westonia) ella
Micromitra (Iphidella) pannula

The overthrust structure, however, is complicated by two or more later fault systems. The older and more conspicuous of these was evidently developed by the stresses induced by the granite intrusion. The intrusion effected a domal uplift of the Paleozoic and Mesozoic rocks, and the force was great enough to rupture the dome in places, forcing the more central portions upward and outward against the outer portions. The strongest of these faults is best exposed on the north side of Little Cottonwood Canyon about half a mile west of Alta (Figs. 2 and 3), where the "lower" quartzite and shale, badly contorted, abut against the "lower" limestone along a steep westward-dipping fault plane. A second similar, but smaller, westward-dipping reverse fault is exposed about three-fourths of a mile east of the first, along the divide between Little Cottonwood Canyon and Mill D South Fork. The effects of these later reverse faults in obscuring the earlier overthrust are shown in Fig. 3. Both of the later reverse faults die out northward along the strike rather rapidly; southward the same, or similar, parallel faults are exposed near the head of American Fork Canyon, and the western one (nearer the granite) appears to continue in a southwestward direction as far as the Silver Lake cirque, beyond which the quartzite belt is cut off by the intrusive granite.

Besides these later reverse faults there are still later normal faults, some of which parallel the reverse faults and serve further to complicate the structure. Only one is indicated in Fig. 3. Some of the normal faults are mineralized, but as the writer's four-day visit to the district was almost wholly confined to surface work, he cannot consider them further than to state that the few veins seen by him, some of which lie along well-defined faults, appear to bear a radiating and concentric relation to the granite mass. Mapping of all the veins in the district may disprove this hasty statement. Whether or not there are important faults still later than the period of mineralization the writer cannot say.

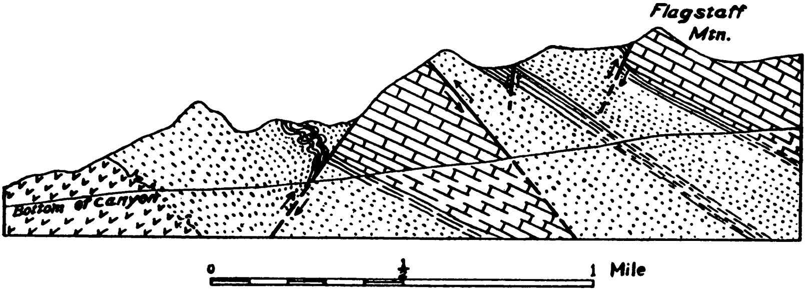

FIG. 3.—N.E.–S.W. section on the northwest side of Little Cottonwood Canyon, northwest of Alta, showing the effect of faulting upon the distribution of the Cambrian quartzite and the Cambrian to Mississippian limestones. The east-dipping overthrust is the oldest, the west-dipping reverse faults are later and directly related to the intrusive granite shown at the left. The normal fault in the central part is only one of several which were not mapped in detail.

It may, however, be well to emphasize the relations of the two limestone belts to the distribution of ore bodies. Both belts contain producing mines, and during the writer's visit, in July, 1912, it is said that certain companies operating in the eastern or "upper" limestone belt were planning to sink to the "lower" belt in the hope of finding new ore bodies. The presence of the overthrust faults, as shown in Fig. 3, gives such a plan little hope of success. It cannot yet be said just how far the overridden belt extends eastward beneath the "upper" quartzite, but it is highly probable that it pinches out within a rather short distance.

Summary of structural evidence.—The "lower" limestone, formerly called the "Ute (Silurian)" by the Fortieth Parallel Survey, is proved to be a part of the Mississippian and older limestones overridden by a slab of the Cambrian quartzite which was formerly called "Ogden" and referred to the Devonian. This overthrust of eastward dip, was broken by at least two parallel reverse faults of steep westward dip which were formed during the domal uplift which accompanied the granite intrusion. Still later normal faults further complicate the structure.

Stratigraphy.—The stratigraphy east of the reversed faults, or from the "upper" quartzite belt upward, consists of a thin belt of Cambrian shale, which grades upward into the great limestone belt. The lowest limestone beds may be Cambrian also, but the greater part of the limestone contains Mississippian fossils. No careful measurements of thickness were made, but a rough estimate shows that there cannot be much more than 2,000 ft., and maybe much less, of pre-Mississippian limestone and shale. This is in marked contrast to the stratigraphy in the northern Wasatch Mountains and in the Uinta Mountains to the east. In the former, Cambrian limestones and shale above the quartzite aggregate 5,415 ft.[1] and are themselves separated from the Mississippian by 1,000 to 1,200 ft. of Ordovician and 1,000 to 1,500 ft. of Silurian and Devonian limestones.[2] In the latter, on the contrary, the entire great limestone belt is only 700 to 1,000 ft. thick, and Weeks[3] correlates its lowest beds with the Mississippian. The upper part he assigns to the Pennsylvanian. The Silurian and Devonian have been shown by Weeks and Ferrier[4] to thin southward and eastward, and they may not be represented so far southward as the Cottonwood district; but the exact stratigraphic relations cannot be accurately determined by mere reconnaissance work.

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[1] C. D. Walcott, "Cambrian Brachiopoda," *Mon. U.S. Geol. Survey*, No. 51, Vol. I (1912), 148–52.

[2] E. Blackwelder, *op. cit.*, pp. 527–28.

[3] F. B. Weeks, "Stratigraphy and Structure of the Uinta Range," *Bull. Geol. Soc. America*, XVIII (1907), 432–41.

[4] F. B. Weeks and W. F. Ferrier, "Phosphate Deposits in Western United States," *Bull. U.S. Geol. Survey*, No. 315 (1906), p. 451; F. B. Weeks, "Stratigraphy and Structure of the Uinta Range," *Bull. Geol. Soc. America*, XVIII (1907) (correlation table). Silurian and Devonian are not represented in the Uinta Range.

The Mississippian limestone is followed upward by a considerable thickness of limestone, shale, and sandstone, which is succeeded by the Weber (Pennsylvanian) quartzite, and the Weber in turn is overlain by the Park City (Permian?) and Mesozoic formations. No measurements of the thickness of any of these formations were made.

THE AMERICAN FORK–ALPINE DISTRICT

The strata along upper American Fork Canyon south of Mary Ellen Gulch are almost entirely of the great limestone belt, striking about parallel to the neighboring granite contact and dipping away from it (see Fig. 2). The dip undulates gently, and at one place erosion has evidently exposed the top of the quartzite, presumably along a low anticlinal flexure; but the one quartzite outcrop found is completely isolated in an area of glacial drift, and its structural relations can only be inferred. Near the great bend in American Fork Canyon the uniformity of strike and dip is interrupted by an anticlinal or domal structure in which the Cambrian quartzite is exposed along the lower canyon walls. The southern part of the dome is cut off by an E.-W. fault, with relative upward movement on the north side. Two miles below the bend, the quartzite is again exposed along the lower canyon walls in a second domal uplift. About midway between this second dome and the town of Alpine to the northwest, the quartzite is again exposed in a third domal uplift, which like the first is broken by a fault. The fault is exposed along the range front and is clearly of the reversed type, with steep northward dip (toward the granite). As these faulted dome structures are essentially small duplicates of the great faulted dome around the intrusive granite, they may indicate the presence of unexposed intrusive granite bosses south of the exposed granite area. This suggestion is strengthened by the fact that the southern granite contact pitches southward beneath the contact-metamorphosed limestones. The southerly pitch is well shown at the Silver Lake cirque about 4 miles east of Lone Peak, where limestone forms the west wall, and quartzite and limestone the east wall, but where granite forms the north wall and the floor.

The quartzite exposures in American Fork Canyon were regarded as Devonian by the Fortieth Parallel Survey, as their exposed thickness was not too great and no other quartzite occurred above them; but since they have the same stratigraphic position as do the fossiliferous Cambrian "upper" quartzite and shale in the Cottonwood district, there can be no reasonable doubt of their Cambrian age. There are several good exposures of shale just above the quartzite areas, and it is in these that fossils are to be expected. South of American Fork Canyon the strata pitch southward, and along the west foothills of Timpanogos Peak, east of Pleasant Grove, the Mississippian limestone reaches nearly or quite down to the level of the Lake Bonneville shore line. Timpanogos Peak was not ascended.

THE PROVO DISTRICT

As only one short day was spent at Provo, remarks will be limited to the two quartzite occurrences along the lower front of Provo Peaks. They are both exposed along anticlines which are in line with each other, but oppositely unsymmetrical. The northern exposure forms a low arch for about 3 miles along the range front, and is nearly bisected by the mouth of Rock Creek Canyon, northeast of Provo. Near the mouth of the Canyon the quartzite is flanked by a still lower body of dark argillaceous limestone, which at the mouth of the canyon is faulted against it. No fossils were found in the limestone, and its physical characters were of too indefinite and general a character to permit a definite correlation with any members of the great limestone belt above the quartzite, though such a correlation is possible. It is also possible that this lower limestone is intercalated within the quartzite. Pebbles of impure limestone were found in a dark conglomerate bed in the quartzite at the canyon mouth, but represented, on weathered surface, a light-gray, finely banded type and not the dark type in question. The pebbles, however, indicate the presence of limestone in Cambrian or earlier time, and an unconformity possibly within the Cambrian.

The quartzite and its overlying shale have a gentle eastward dip for a short distance, but just above the mouth of the canyon they steepen abruptly and are slightly overturned, dipping 80° westward. The great limestone belt lies above the overturned portion with a very gentle and uniform easterly dip, as if it had slid bodily westward over the quartzite and shale; but, as the writer entered the canyon at sunset he had no opportunity to get more than a hasty glance at the structure. Mr. Emmons remarked that the structure, as seen from the canyon bottom, appeared to be a strong unconformity, but that examination the whole length of the canyon proved the structure to be an S-shaped fold with only its upper half exposed.[1] The limestone cliffs show the same succession of limestones as that which overlies the Cambrian quartzite and shale in the Cottonwood district, and the quartzite exposures at Provo are therefore to be assigned to the Cambrian, and not to the Devonian as was done by the Fortieth Parallel Survey.

The southern quartzite occurrence, southeast of Provo, also forms an arch along the range front, cut by Slate Creek Canyon. In this case, however, the western limb is very steep. The quartzite is exposed approximately along the axis and is flanked by overlying limestone dipping steeply westward. The east limb, which can be studied along the walls of Slate Creek Canyon, dips very gently and is overlain by about 200 ft. of shale and the regular succession of limestone beds. The conglomerate bed with light-gray limestone and other pebbles is exposed in the canyon near its mouth, and beneath it in the creek bed is a doubtful outcrop of dark bluish-black limestone similar to that flanking northern quartzite exposure. The evidence in the two cases, though not absolutely convincing, is thus consistent and points to the existence of a local limestone horizon below, or within, the quartzite, and also to the existence of an unconformity below the exposed part of the Provo section, presumably in Lower Cambrian time.[2] Limestone beds of Middle Cambrian, and one small bed of Lower Cambrian or even earlier age, were found by the writer intercalated in the great quartzite series of the Simpson Mountains north of the

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[1] *Op. cit.*, pp. 345–46.

[2] According to Walcott ("Cambrian Sections of the Cordilleran Area," *Smithsonian Inst. Misc. Coll.*, 1908), the first 100 ft. of shale above the basal quartzite in Big Cottonwood Canyon are Lower Cambrian and next 150 ft. are Middle Cambrian. The quartzite at Provo, 25 to 30 miles farther south, may therefore also be regarded as approximately at the top of the Lower Cambrian.

Sevier Desert in June, 1912, but none farther east are known save this obscure Provo occurrence.

THE SANTAQUIN–MOUNT NEBO DISTRICT

Santaquin is about 18 miles S.S.W. of Provo. The Wasatch Range from here southward to Mount Nebo is interesting both from a stratigraphic and structural standpoint.

Stratigraphy.—The oldest formation in the district is a band of pre-Cambrian gneissoid granite with large included bodies of schists, exposed for 2 miles or more along the lower range from east of Santaquin. It is quite different in texture from the granite of the Cottonwood district, and is overlain unconformably by Cambrian quartzite, the basal beds of which contain quartz and coarse red feldspar fragments derived from the pegmatitic facies of the granite. The quartzite formation dips 28° east and does not appear to be over 800 ft. thick. It varies in texture from conglomerate to shale, and in color from white to dark red and brown. In its upper half are a few dark-green beds with a high iron content. The quartzite passes upward into shale in which Cambrian trilobites have been found. The shale is followed by alternating beds of argillaceous limestone and shale, and finally by continuous limestone which at the top of the ridge includes a part of the upper Mississippian "intercalated series."

The Mississippian limestone is abundantly fossiliferous, and the lowest Mississippian fossils were found at a horizon about 2,400 ft. above the top of the quartzite. No fossils in the intervening limestones were found, but the lithologic succession as a whole is very similar to that of the lower half of the limestones of the Tintic district, about 20 miles to the southwest, which total 3,500 ft. in thickness and are chiefly or wholly Cambrian. No unconformity was detected, but so far as comparisons can be made the Mississippian limestones in the Santaquin, as well as in the Cottonwood district, lie on a much thinner series of limestone than is the case in the Tintic district to the west or in the northern Wasatch Mountains.

The upper Mississippian "intercalated series" is overlain unconformably on the east flank of the ridge by a coarse reddish conglomerate, part of which consists of quartzite, chert, and limestone pebbles, and part of calcareous beds full of peculiar concretionary growths. Some of these concretions resemble shells in form, and one undoubted gastropod was found, which Dr. T. W. Stanton of the Survey says may be a fresh-water Eocene species. The unconformity implies the removal by erosion of the Weber quartzite, the Park City formation, and the Mesozoic formations which overlie these formations in the Park City district. Overlying the Eocene conglomerate is a coarse andesitic (or latitic) breccia. Its outcrops are weathered and largely reduced to aggregates of loose cobbles some nearly a foot in diameter, and the nature of its contact with the underlying conglomerate, whether conformable or unconformable, could not be determined.[1] Intrusive volcanic rocks are limited to a few dikes, also of andesitic or latitic character.

In the low hills south and southwest of Santaquin, a veneer of Eocene conglomerate with remnants of the volcanic breccia overlies limestones of pre-Mississippian (probably Cambrian) age, and 35 miles farther southwest, in the Sevier River Canyon, the same Tertiary sequence of rocks rests unconformably upon the Cambrian quartzite. Nearly the whole Paleozoic, as well as the Mesozoic, section in central Utah is thus beveled off by this unconformity, as is the case in the Uinta Mountains in northeastern Utah.[2]

The last two Eocene occurrences mentioned are somewhat farther west and north than any previously mapped, and it is believed that they are not far from the original limits of the Eocene in this region; for in Long Ridge and the East Tintic Mountains, about 12 miles southwest of Santaquin, the same type of andesitic breccia rests either directly upon Paleozoic rocks, or is separated from them by an intervening body of effusive rhyolite, and no sedimentary rocks later than Paleozoic have been found.

Structure.—The principal structural features in the Santaquin–Mount Nebo district are faults, including doubtful overthrusts of

[1] C. K. Leith and E. C. Harder. (*Bull. U.S. Geol. Survey*, No. 338 (1908), pp. 18 and 21) have proved an unconformity between Cretaceous and Eocene beds in the Iron Springs district of southern Utah and a later unconformity between the Eocene beds and Miocene lavas.

[2] F. C. Weeks, *op. cit.*, p. 442.

N.-S. trend and a series of N.-S. and E.-W. block faults of the Basin Range type (see Fig. 4). The former are so poorly exposed, their courses so nearly parallel to the N.-S. system of the block faults, and, in some places, the rocks along them so free from severe crumpling or crushing, that the writer is not fully convinced of their overthrust character.

Overthrusts: East of Santaquin the northern part of the pre-Cambrian granite appears to overlie quartzite, but the contact is concealed by float. A little farther northward, however, the granite pinches out and the main body of Cambrian quartzite overlies a dark brecciated limestone, which passes downward into shale and quartzite. This lower quartzite exposure, in turn, overlies fossiliferous Mississippian limestone, which is very free from any of the crumpling or brecciation which is likely to accompany overthrusting. The Mississippian limestone is underlain conformably by fossiliferous Cambrian shale and a third quartzite exposure.

The pre-Cambrian granite southward disappears beneath a high alluvial fan which is now trenched by Santaquin Creek; but the main Cambrian quartzite body continues, and at its southernmost exposure rests again upon fossiliferous Mississippian limestone, which, as in the other instance, is surprisingly free from contortions and crushing. So far as the positions of the rocks are concerned, reverse or overthrust faulting seems the only interpretation; but the absence of disturbance in the overridden limestone is not easily explained.

At the mouth of Green Canyon, 8 miles south of Santaquin, an extremely brecciated and, so far as seen, non-fossiliferous limestone dips eastward beneath Cambrian quartzite, and here is the most convincing evidence of an overthrust, although time did not permit a thorough study of the immediate contact. A tunnel of the Excelsior Mining Company has been driven through the limestone into the quartzite, but the entrance to it was locked at the time of the writer's visit. No fossils were found in the underlying limestone, but the presence on the dump of fragments of a highly carbonaceous and finely pyritic bed, similar to two found elsewhere in the Mississippian of the southern Wasatch Mountains and of the Tintic district, gives a clue to the age of the limestone, and accords with the structural relations in showing the fault to be an overthrust.

Block faults: A striking difference between the faults just described and the undoubted normal, or block, faults of the district is that the latter are marked by longitudinal and, to a less degree, by transverse valleys, whereas those interpreted as overthrusts appear unrelated to topography. From Santaquin southward nearly to Green Canyon (see Fig. 4) the western side of the range is composed of parallel ridges separated by remarkably straight N.-S. canyons. The strata on opposite sides of these canyons are quite discordant. For example, just north of Wash Canyon (6 miles south of Santaquin), the upper Mississippian "intercalated series"

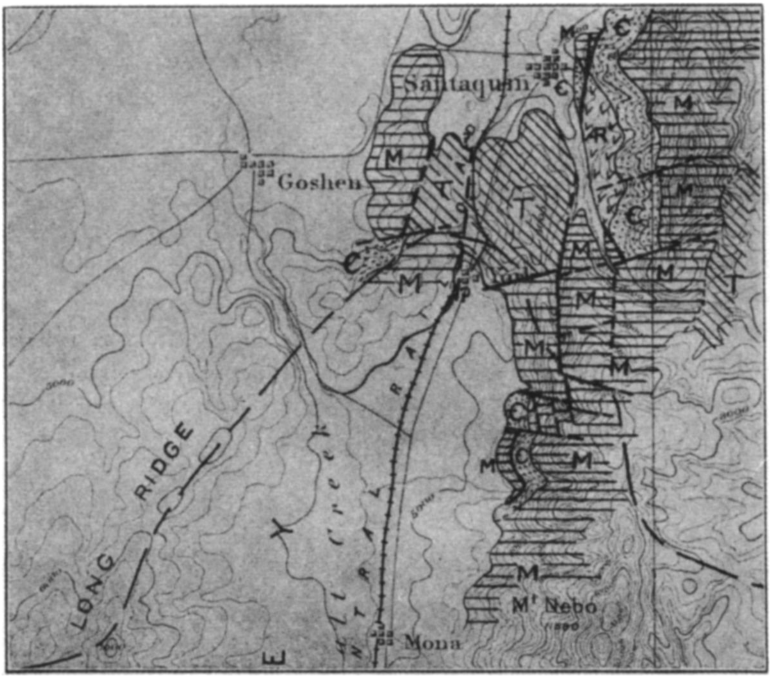

FIG. 4.—Geologic map of the Santaquin–Mount Nebo district showing overthrusts and block faults. /R = pre-Cambrian granite, -Є = Cambrian quartzite; *M* = Mississippian and earlier limestones; *T* = Tertiary conglomerate and volcanics. Topographic base from the Manti sheet, United States Geological Survey.

with gentle easterly dip forms the low western ridge, and the pre-Mississippian limestones lie directly opposite on the west face of the main ridge. The "intercalated series" forms the crest of the main ridge, about 2,000 ft. above the western ridge. To the south across Wash Canyon, which follows a nearly E.-W. fault, the "intercalated series" is followed by Cambrian quartzite and limestones, and farther south a second E.-W. fault cuts off the Green Canyon overthrust. To the north, the "intercalated series" of the western ridge abruptly gives way, at another E.-W. fault, to the Eocene sediments and later volcanic breccia, which cover the low hills west of Santaquin Canyon, whereas the face of the main ridge east of the canyon is made up of the pre-Cambrian complex and lower Paleozoic strata, and the Tertiary beds are found only along its eastern base. The most obvious E.-W. (N. 70° E.) fault in the district is on the west side of the main ridge in a ravine just north of Santaquin Canyon, where the entire Cambrian quartzite and the overridden Mississippian limestone beneath it are cut off and followed on the south side by the lower (probably Cambrian) limestone beds.

It is of some interest to add that faulting later than the Tertiary volcanic flows was found by the writer last year in the East Tintic district and that this accords with the more convincing evidence in the Santaquin–Mount Nebo district, where the presence of faulted Eocene conglomerate and late or post-Eocene volcanic breccia places the time of the faulting and range uplifts not earlier than Miocene, thus confirming existing conclusions regarding the age of the basin ranges.

SUMMARY

In the Cottonwood district the "Ute" limestone and "Ogden" quartzite recognized by the Fortieth Parallel Survey are shown to be respectively parts of the Mississippian (and older) limestones and Cambrian quartzite.

The latter has overridden the former along an overthrust fault of easterly dip.

This overthrust is broken by at least two later reverse faults of westerly dip which were formed during the domal uplift induced by the granite intrusion.

Still later normal faults further complicate the structure.

The Mississippian limestone does not appear to be over 2,000 ft., and may be much less, above the Cambrian quartzite. The thickness of pre-Mississippian limestones is much less than in the northern Wasatch country, and greater than in the Uinta Mountains.

Cambrian quartzite, formerly called "Ogden (Devonian)," is exposed in three domal uplifts in the American Fork–Alpine district. Two of the domes are faulted, and the similarity of the structure to that in the Cottonwood district suggests that outlying bosses of the granite may underlie the domes.

Cambrian quartzite in the Provo district is exposed along two anticlines in line with each other, but oppositely unsymmetrical. A conglomerate bed in the quartzite contains impure limestone pebbles, indicating the existence of limestone of Cambrian or earlier age and an unconformity, presumably in the Lower Cambrian. Obscure exposures of dark limestone may represent a local bed intercalated in the quartzite, but the evidence at hand is not convincing.

In the Santaquin–Mount Nebo district the lowest exposed rocks are pre-Cambrian granite and schist, overlain unconformably by about 800 ft. of Cambrian quartzite, which is followed by 2,500 ft. of shale and limestone, in part or wholly Cambrian, and by Mississippian limestone. The upper Mississippian "intercalated series" east of Santaquin is overlain unconformably by Eocene conglomerate and volcanic breccia. To the west and southwest, the Eocene conglomerate rests upon pre-Mississippian limestone and Cambrian quartzite, proving the unconformity to have beveled off nearly the entire Paleozoic, as well as the Mesozoic, section. These latter occurrences mark approximately the western limit of Eocene sedimentation in central Utah.

Both overthrust and block faults are present in the Santaquin–Mount Nebo district. The former are for the most part obscure, but in each case are marked by Cambrian quartzite resting upon Mississippian limestone. The block faults are marked by N.-S. and E.-W. canyons, and are shown to be of post-Eocene age.